DGRP-TR-62-4

ESTABLISHING PROVEN DESIGN CRITERIA FOR CRYOGENIC BOOST TANKS

QUARTERLY PROGRESS REPORT
PERIOD ENDING 31 JANUARY, 1962

J. G. Connelly
B. R. Etheridge

BEECHCRAFT RESEARCH AND DEVELOPMENT, INC.
BOULDER, COLORADO

BEECHCRAFT ENGINEERING REPORT NO. 13531

CONTRACT AF33(616)-5154
SUPPLEMENT S3(59-207)
PROJECT NO. 3084
TASK NO. 30304

112 350

MARCH 1962

DGRPT
AIR FORCE FLIGHT TEST CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
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FOREWORD

This contract was initiated by the Propulsion Laboratory, Wright Air Developing Center, Wright-Patterson Air Force Base, Ohio, and for the past three years has been monitored by the Rocket Propulsion Laboratory of the Air Force Flight Test Center, Edwards Air Force Base, California. The work upon which this report is based is being accomplished by Beechcraft Research and Development, Inc., Boulder, Colorado, under Air Force Contract AF33(616)-5154, Supplement S3(59-207). Mr. J. Branigan of the Rocket Propulsion Laboratory is the Air Force Project Engineer in charge of the work done under this contract.

This is the tenth quarterly report submitted per Item IV, Part I of the S3(59-207) supplement to the contract. This report covers all work accomplished from 1 November, 1961, to 31 January, 1962.

ABSTRACT

Status of the progress on the thermal simulation test program during the tenth reporting period of the contract is reported.

In the thermal simulation test program the progress on the 7,000 gallon test tank system fabrication, pre-test program and the thermal test facility is reported. A description of the fabrication progress and hydrostatic test of the titanium test tank and thermal testing of the stainless steel test tank is presented. A description of the facility program is presented.

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

This is the tenth progress report on work being performed under Contract AF33(616)-5154, Supplement S3(59-207), involving research and development of cryogenic propellant tanks for rocket vehicles. This program is a continuation of an investigation of propellant tank design problems begun by Beechcraft Research and Development, Inc., in July, 1957.

During the original study program, it was determined that actual development and testing work would provide data which could be used in the design of actual flight items. Therefore, a thermal simulation program was devised which would require a test tank with a capacity of 7,000 gallons. A 7,000 gallon stainless steel tank and a 7,000 gallon titanium tank have been fabricated for this program.

1.0 THERMAL TEST PROGRAM

This section will describe the progress of tank fabrication, testing, and thermal facility reactivation during this quarterly report period. The following subsections will be devoted to a description of the subject topics.

(a) 7,000 gallon titanium test tank system
(b) 7,000 gallon stainless steel test tank system
(c) Thermal test facility

1.1 7,000 Gallon Titanium Test Tank System

This section will be described in two parts: tank fabrication progress and hydrostatic testing of the completed vessel.

1.1.1 Tank Fabrication Progress

At the close of the last quarterly report, the completion of the forward half of the tank was reported. During November, 1961, assembly of the aft half of the tank was begun. The sequence of assembly is as follows:

(a) The completed aft head assembly was mounted on the horizontal lathe and trimmed to print dimensions. The transition band that joins the head to cylinder was then trimmed to match the head and fitted together for welding. With careful attention given to the fitting operation, the welding proceeded without difficulty resulting in a satisfactory joint.

(b) After completing the splice band and head weld, the aft skirt was fitted to the shoulder machined into the splice band. The weld was made without difficulty, completing the aft head assembly. Figure 1 shows the welding setup and the actual welding taking place. Figure 2 shows the completed aft head assembly.

(c) After completing the head assembly, the aft cylinder section (in storage from previous fabrication) was trimmed to fit the diameter of the aft head and the closure weld was made. The cylinder section was then mounted on the lathe and trimmed to match the aft head. The weld was made without difficulty and the aft half of the tank was completed except for final trim to match the forward half. All welds in the tank half are 100% X-ray examined and of good quality. Figure 3 shows the weld setup for joining the cylinder section to the aft head. Figure 4 shows the completed aft half of the tank.

(d) Final assembly of the tank was accomplished the latter part of November, 1961. The final weld joining the two tank halves was made on the horizontal lathe and X-ray examination

FIGURE 1
PHOTOGRAPH OF WELDING SKIRT TO AFT HEAD ASSEMBLY

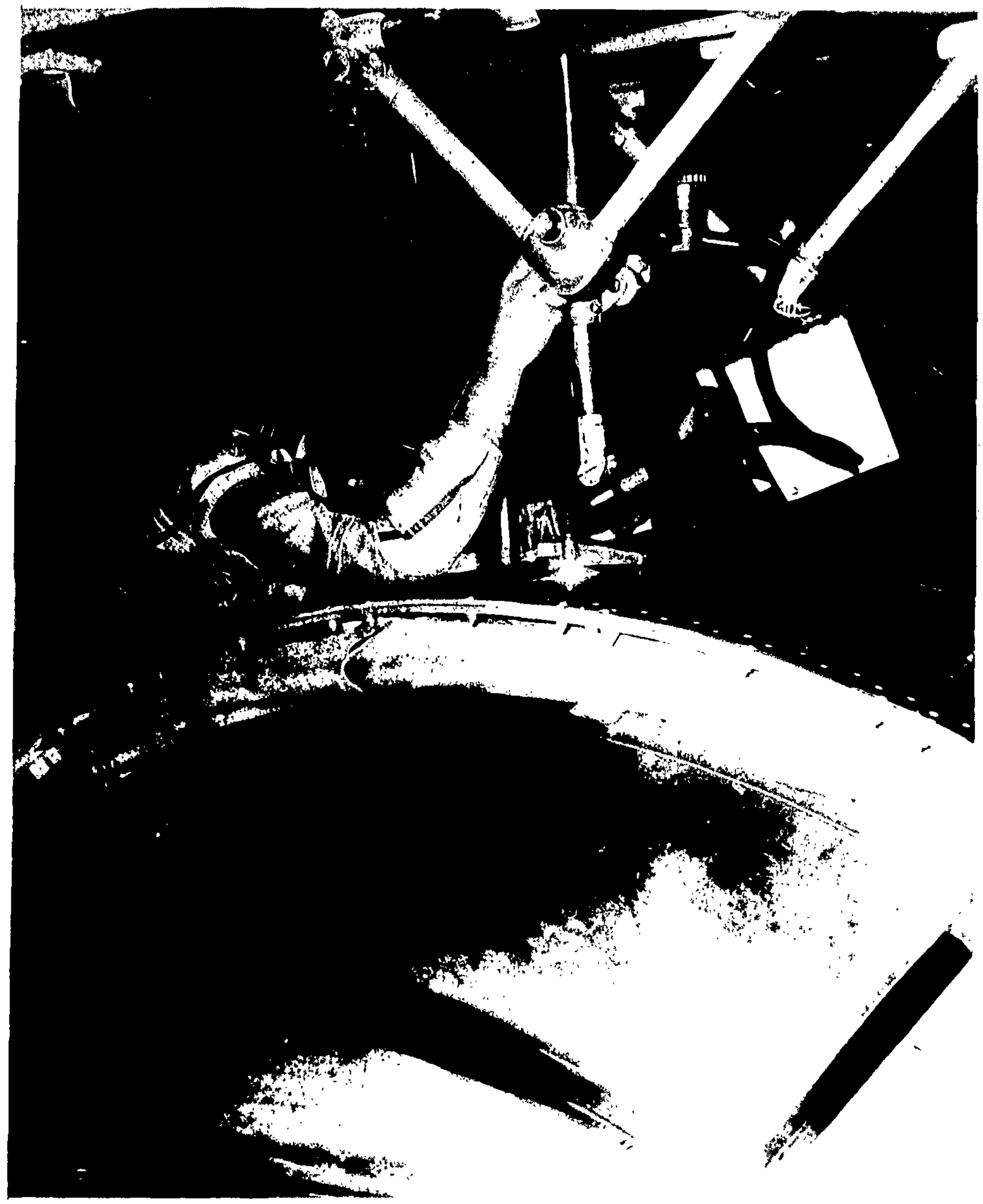


FIGURE 2
PHOTOGRAPH OF COMPLETED AFT HEAD ASSEMBLY

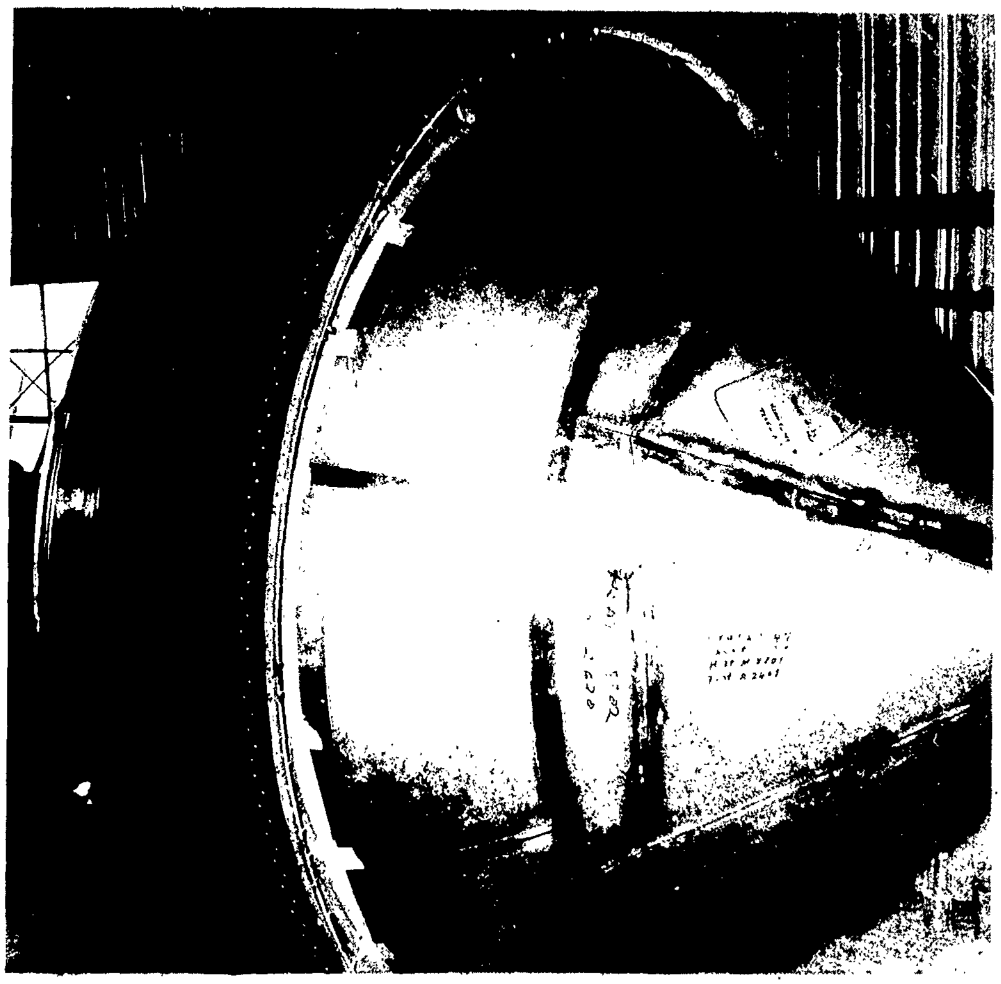
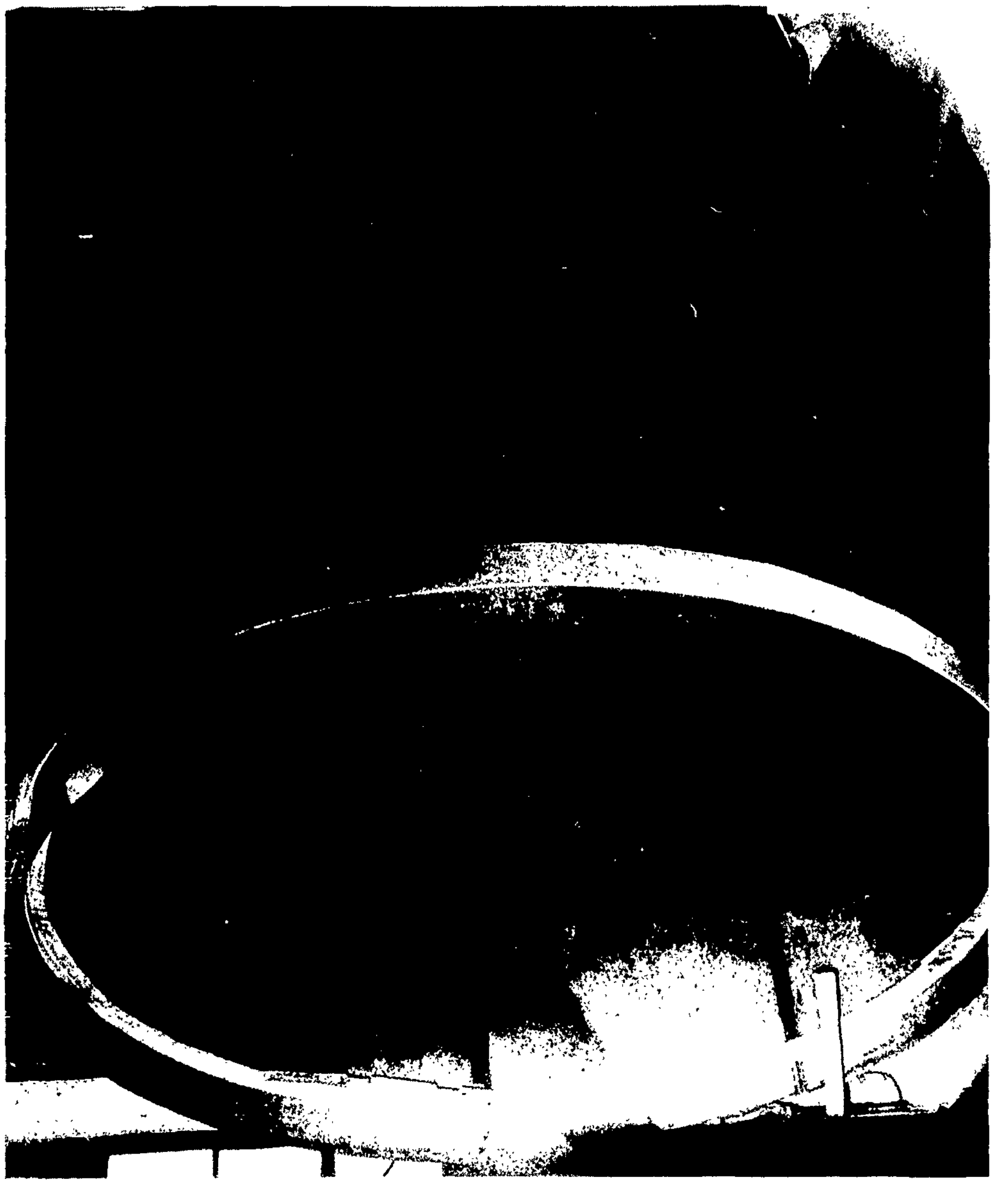


FIGURE 3
PHOTOGRAPH OF WELDING CYLINDER SECTION TO AFT HEAD ASSEMBLY

FIGURE 4
PHOTOGRAPH OF COMPLETED AFT HALF OF TANK



showed the weld was of excellent quality. This completes the titanium tank except for addition of an internal vent line which will be added after hydrostatic testing of the tank is accomplished. Figure 5 shows the completed tank mounted on the lathe.

1.1.2 Hydrostatic Test

This section will describe the hydrostatic testing of the titanium tank in two parts: test preparations to include tank support, plumbing, and instrumentation and testing to include procedures and results.

1.1.2.1 Test Preparations

Prior to filling the tank with water for testing, various preparations were necessary. These preparations are discussed in the following subsections.

1.1.2.1.1 Handling and Transporting

Prior to moving the tank to the test area, all openings were sealed and the tank was pressurized to 3 psig with helium gas. A leak check was then performed covering all weld seams and cover plates. No leakage was indicated by the helium mass spectrometer used.

The tank was left pressurized for the moving operation. The handling fixture designed for use in transporting the stainless steel test tank previously was also used for the titanium tank. As a part of preparations, the annulus of each end of the tank formed by the skirt and head was to be filled with a urethane foam-in-place plastic. To accomplish this, the tank would have to be suspended with each end in the upright position. Figure 6 shows the area to be filled with foam.

During the handling operation while still in the shop area, a crack was discovered in the weld joint joining the forward skirt to the splice band. This area had been repaired once before when a similar crack, caused by a failure of argon gas through the welding tip, developed. Approximately 1-1/2" of weld was made before the gas failure was discovered. The resulting crack in the weld was cleaned of contamination and repaired with apparent success. However, when the tank was subjected to vibrations and stresses during handling the crack reoccurred. It was decided that further repair would not be successful and that the crack would be stop drilled to contain the damaged area and prevent the crack from growing. This operation worked very well.

Since the skirt is primarily for support during hydrostatic testing and does not form a part of the tank itself, it was decided to hydrostat the tank in one position only, using the good skirt for suspension. This would eliminate the possibility of a skirt failure while supporting the tank full of water, which would destroy the tank itself.

FIGURE 5
PHOTOGRAPH SHOWING COMPLETED TITANIUM TANK

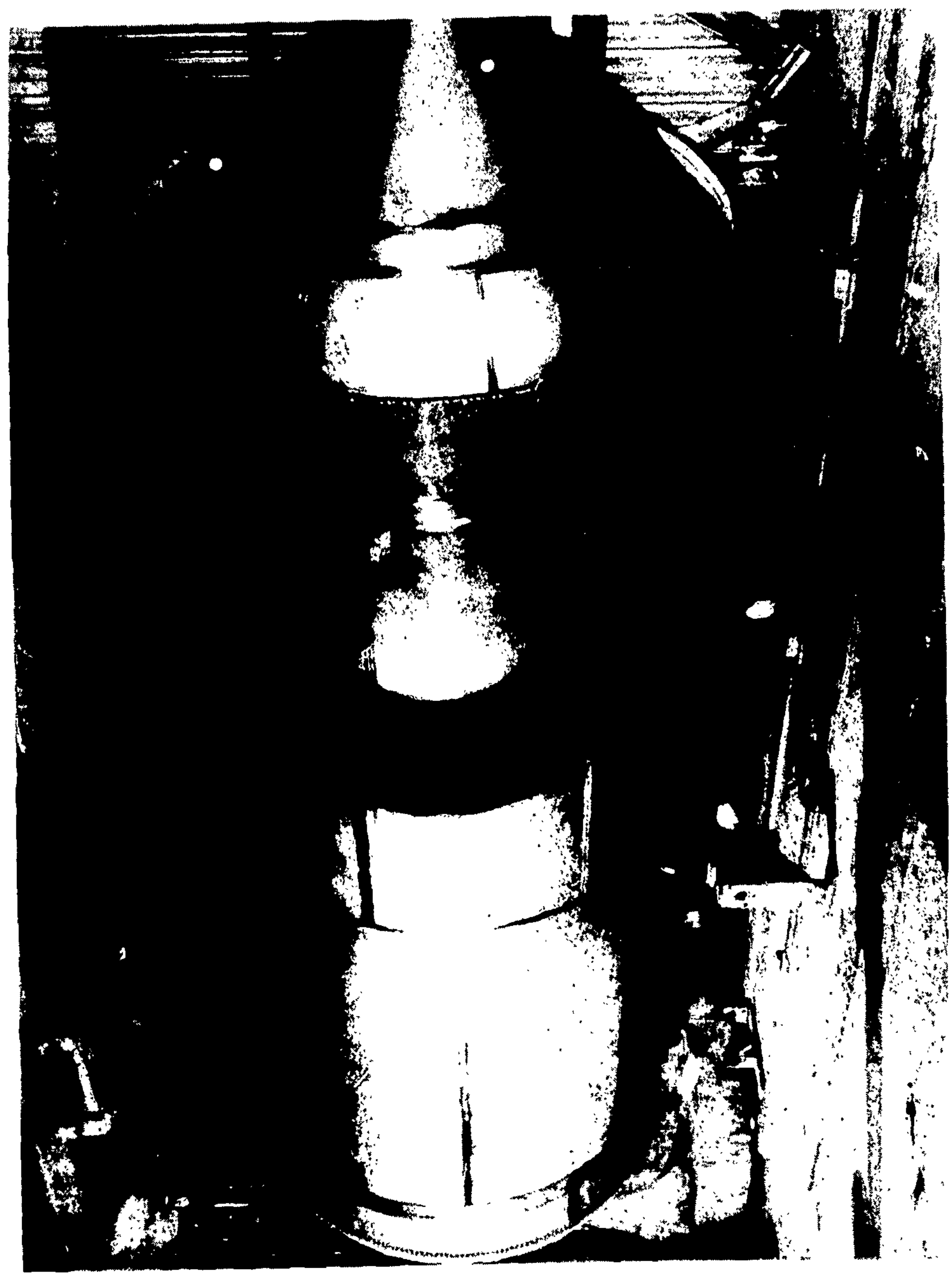
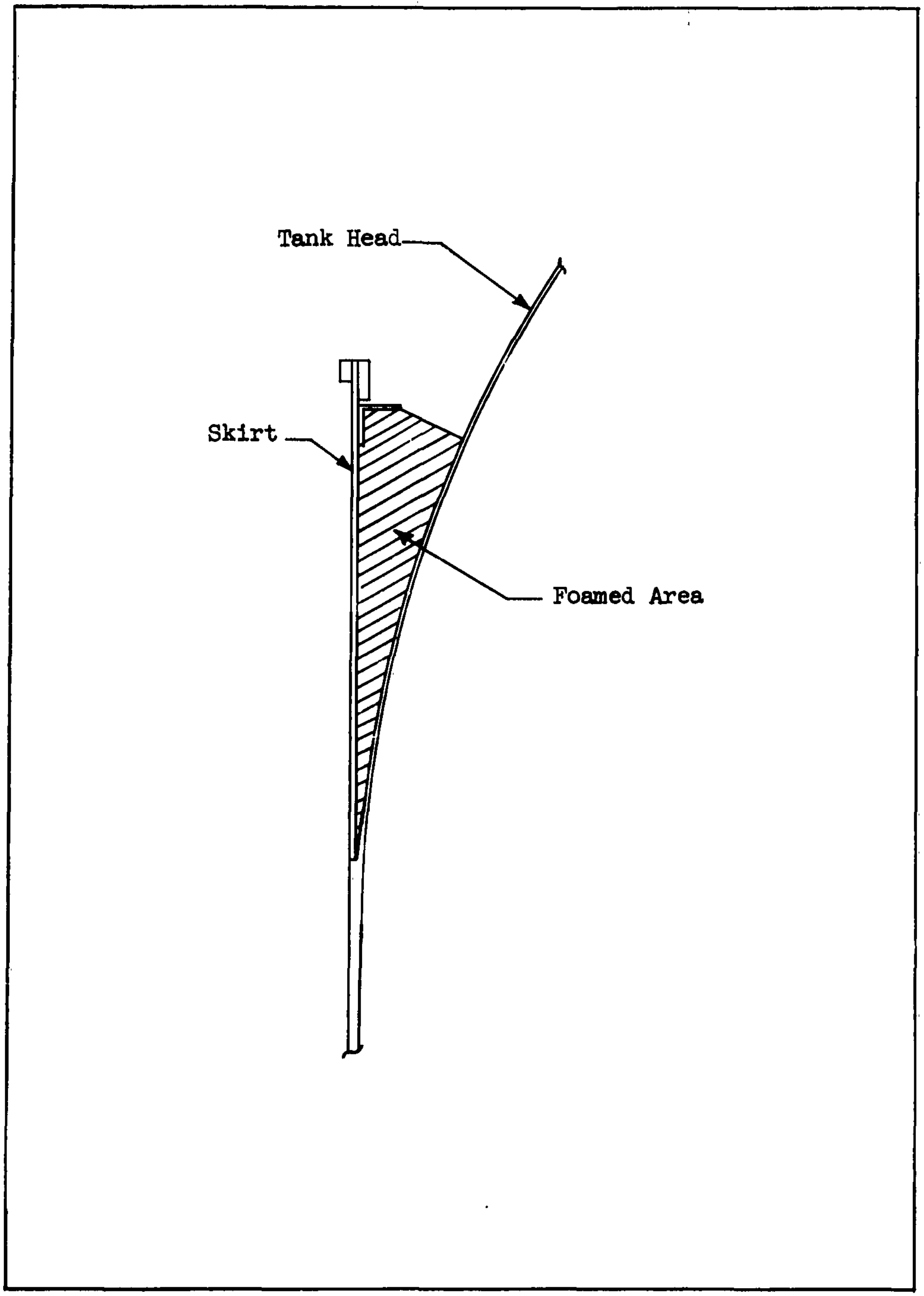


FIGURE 6
CROSS SECTION OF HEAD SHOWING
AREA FILLED WITH FOAM



The tank was first suspended with the forward head in the upright position. The annulus was then filled with the urethane foam. The position of the tank was reversed with the aft head in the upright position and the annulus filled with urethane foam. The tank was then in the desired position for the hydrostatic test, the weight of the filled tank being supported by the skirt with 100% good weld attachment. Figure 7 shows the tank in position for the hydrostatic test.

1.1.2.1.2 Instrumentation

To record the strain experienced by various parts of the tank shell, strain gauges were installed at those points calculated to be most critical. A total of 50 gauges was installed, 41 on the outer surface and 19 on the inner surface.

A series of thermocouples, distributed in a vertical line from the lower head to the upper head, was installed to record any changes of temperature while the test was in progress. All strain gauges and thermocouples were then connected into a harness leading to the recording instruments located in a remote area. The instrumentation was completed by adding a fill warning system at the top of the tank to sound a buzzer when the water level would be within 12" of the top. Figure 8 shows the location of strain gauge points and the thermocouples for skin temperatures. Fifty strain gauges were read directly from an SR-4 balance type strain indicator. Ten of the gauges (F-1, F-9, F-36, P-13, F-17, P-8, F-39, F-12, F-2, F-38) were connected to 10 channels of a Minneapolis-Honeywell Vistacorder for a continuous record of the test. Also connected to the vistacorder were the 6 temperature thermocouples and the pressure at the top and bottom of the tank.

1.1.2.1.3 Plumbing

Figure 9 shows a schematic of the plumbing for filling and pressurization during the hydrostatic test. The pressurization and vent valves were controlled from a remote point. The hook-up provided for automatic venting to prevent overpressurization of the tank during filling and testing. The rate of fill would be monitored by a turbine meter and the total accumulative gallonage continuously indicated.

1.1.2.2 Testing

The hydrostatic test procedure that was followed during this program is outlined in Engineering Test Request No. 4446 described elsewhere in this report. The results of testing and the conclusions drawn are discussed in the following paragraphs.

Figure 10 is a curve showing the total pressure applied versus strain. The pressure values shown do not include the hydrostatic head which had a value of 10 lbs/in^2.

Figures 11 and 12 are curves showing the actual and theoretical stresses at various points on the tank. The tank is divided into 14 stations to aid in locating the area of stresses discussed. Station 1 is located at the manhole cover plate of the forward head.

Comparison of Actual and Theoretical Stresses

In comparing actual and theoretical stresses, it is seen that in almost every case the actual stresses are less than those predicted by theory. This is largely a result of the fact that a conservative analysis was made in determining the theoretical stresses. In areas of pure membrane stress the minimum skin gage was chosen in computing stresses. The worst possible conditions were chosen at discontinuities. Since these conditions did not exist in the test tank, the measured stresses normally were less than the theoretical values.

There are other more specific factors which affect the differences in stress. These factors will be discussed for each station as follows.

Station 1 (Center of Manhole Cover)

The actual and theoretical stresses were found to be nearly equal at this location. The strain gage was far enough from any discontinuity to be unaffected by any concentrations. In addition, the skin gage must have been nearly equal to that used in the theoretical calculation.

Station 2 and 12 (Hemisphere or Knuckle)

Excellent pressure strain curves were obtained in this area and since no discontinuities were near the gages, it must be concluded that stress differences are due to a variation in skin thickness. The theoretical stress was determined using a skin gage of .017 inches and resulted in a stress of 57,000 lbs/in^2. If a skin gage of .021 is assumed, the theoretical stress is found to be 47,200 lbs/in^2, which is only 2,400 lbs/in^2 greater than the measured stress. This difference may easily be accounted for by experimental error, differences in Poisson's ratio, modulus of elasticity, or other similar factors.

Station 3 and 11 (Hemisphere-Foam Juncture)

In the theoretical analysis, complete fixity was assumed at these stations because of the foam filler between the skirt and tank. Because of this, the only stress in the circumferential direction is from Poisson's effect caused by bending in the meridional direction. The curves show the circumferential stress to be much larger than that predicted by theory. This must be caused by an expansion in the circumferential direction which indicates that the foam did not produce fixed ended conditions. The result of this effect on the meridional stresses is shown by the curve. Gage F-32, which is on the outside of the tank, indicates a stress

which is higher than that predicted by theory. This is to be expected since the assumed fixed end condition would produce a higher bending moment than would result from an elastic condition of the foam filler. The reverse effect of the decreased bending moment is shown by gage F-15, which is on the inside of the tank.

Station 4 and 10 (Cylinder-Hemisphere Juncture)

Some experimental error is believed to exist at one or both of these points because of the large stress difference between gages 17 and 25. These two gages should show nearly equal stresses but gage 17 indicated a much higher stress than gage 25. Because of this condition it is felt that the recorded data for these gages is unreliable.

Station 5, 7, and 9 (Cylinder Weld and Base Material)

Stresses at these stations demonstrate the effect of the increased modulus of elasticity of the weld in that there is a decrease in the circumferential stress from that experienced in the pure membrane areas. The effect is small and produces no serious design problems. It is unfortunate that the gages reading meridional strain did not respond properly; therefore, no indication of bending stress was obtained.

Station 6 and 8 (Cylinder)

Any difference in stresses at these points is probably due to variations in skin thickness or material properties. All gages in these areas showed good agreement; therefore, it must be concluded that little experimental error exists.

Station 13 and 14 (Cone and Knuckle)

Meridional stress values show fairly good agreement but a large difference in circumferential stresses exists. A portion of this difference may be explained by variations in skin gages or material properties but at this time it is felt that other differences exist.

Station A and B (Rings)

A comparison of the actual and theoretical stresses was not made in Figures 11 and 12. The actual stresses were generally lower than the theoretical values. Again, a portion of this difference may be explained by differences in material properties or skin gage. This is particularly true with gages F-39 through F-42. But, at the manhole ring where discontinuity stresses were quite high theoretically, the actual and theoretical stresses differed almost by a factor of two. The actual stresses were only slightly different than those at the vent ring. These facts indicate that the stress concentrations at a discontinuity are not as serious as the theoretical analysis indicated.

FIGURE 7
PHOTOGRAPH SHOWING TANK IN POSITION FOR HYDROSTATIC TEST

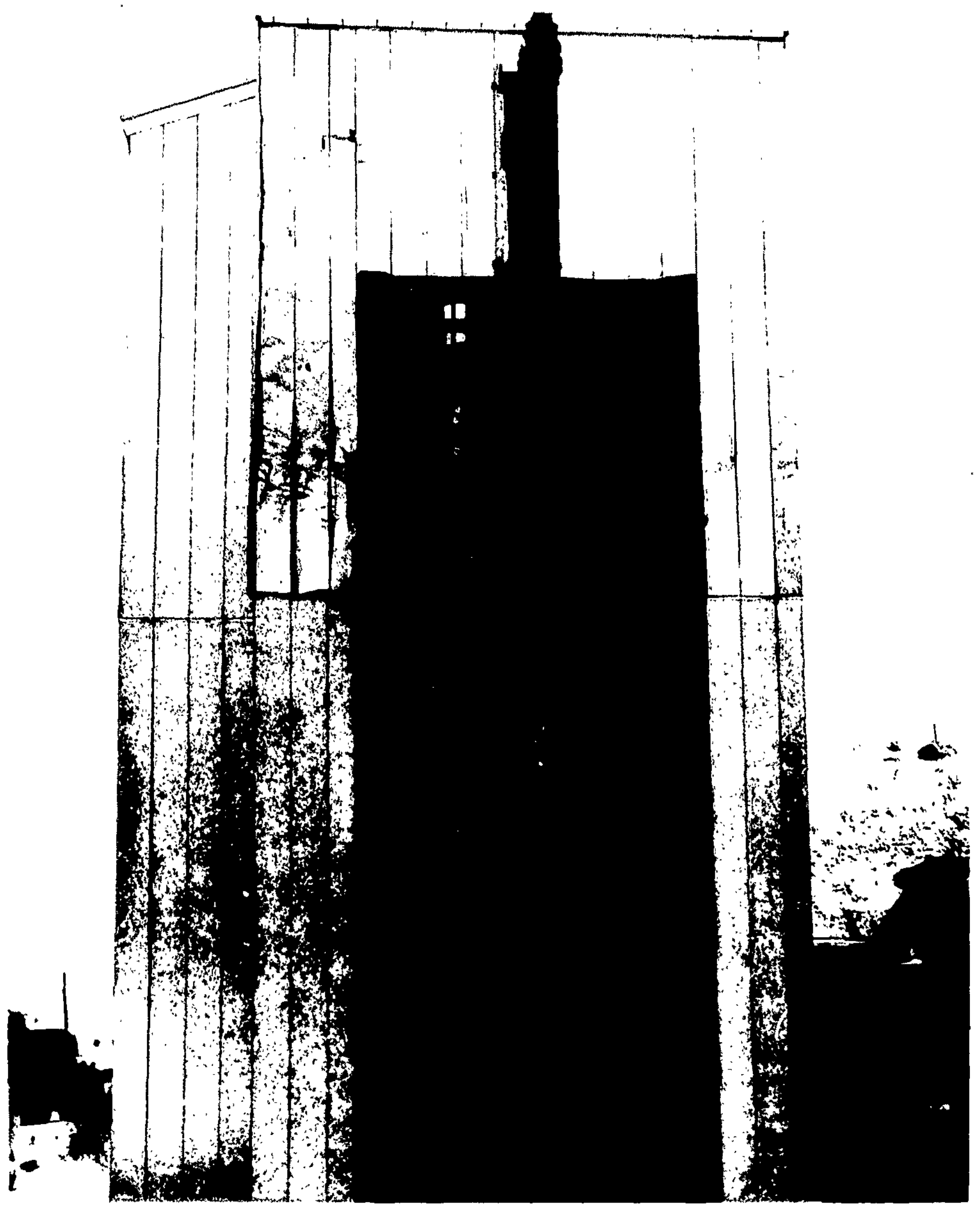


FIGURE 8
LOCATION OF STRAIN GAUGES
DURING HYDROSTATIC TEST

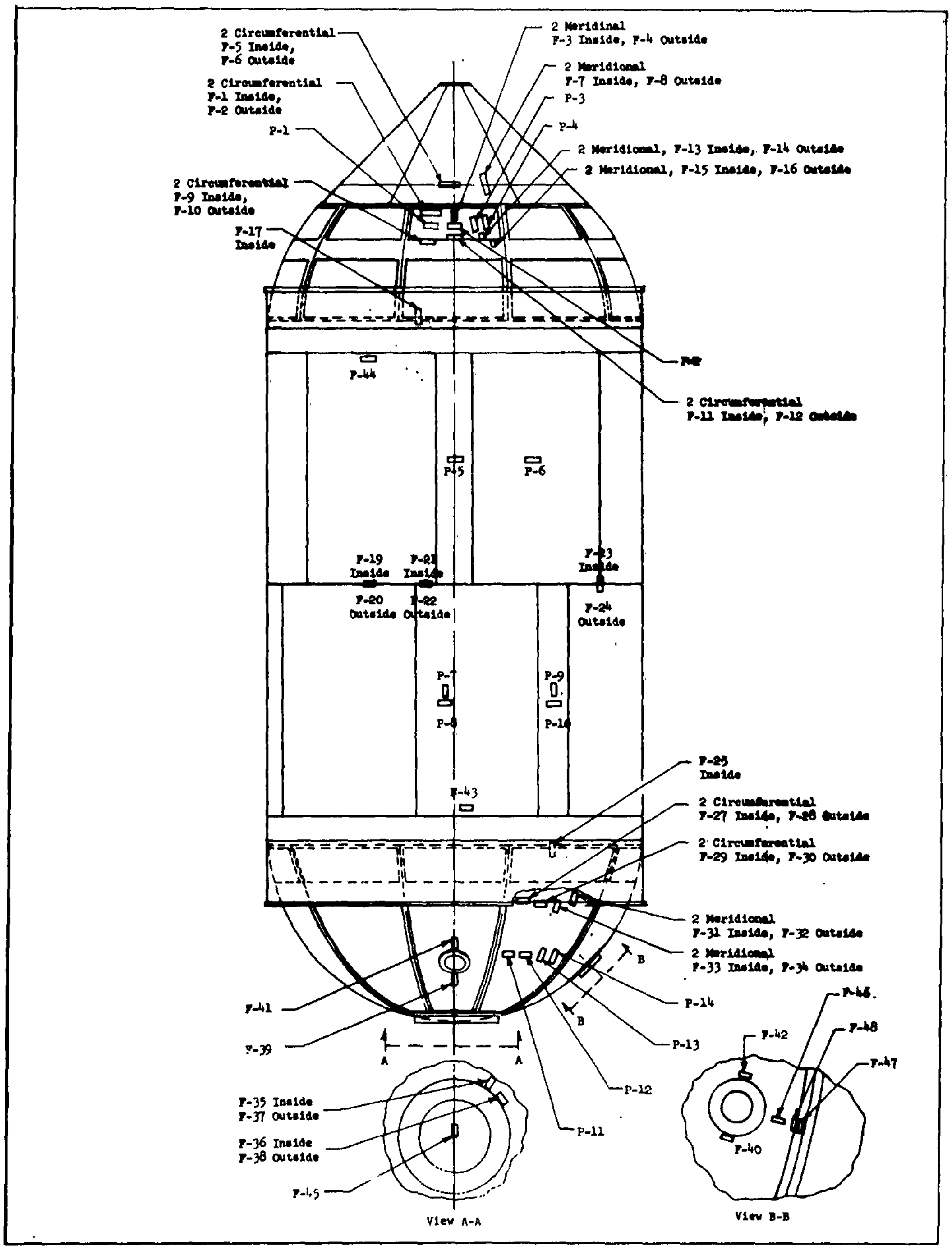


FIGURE 9

PLUMBING SCHEMATIC FOR HYDROSTATIC TEST

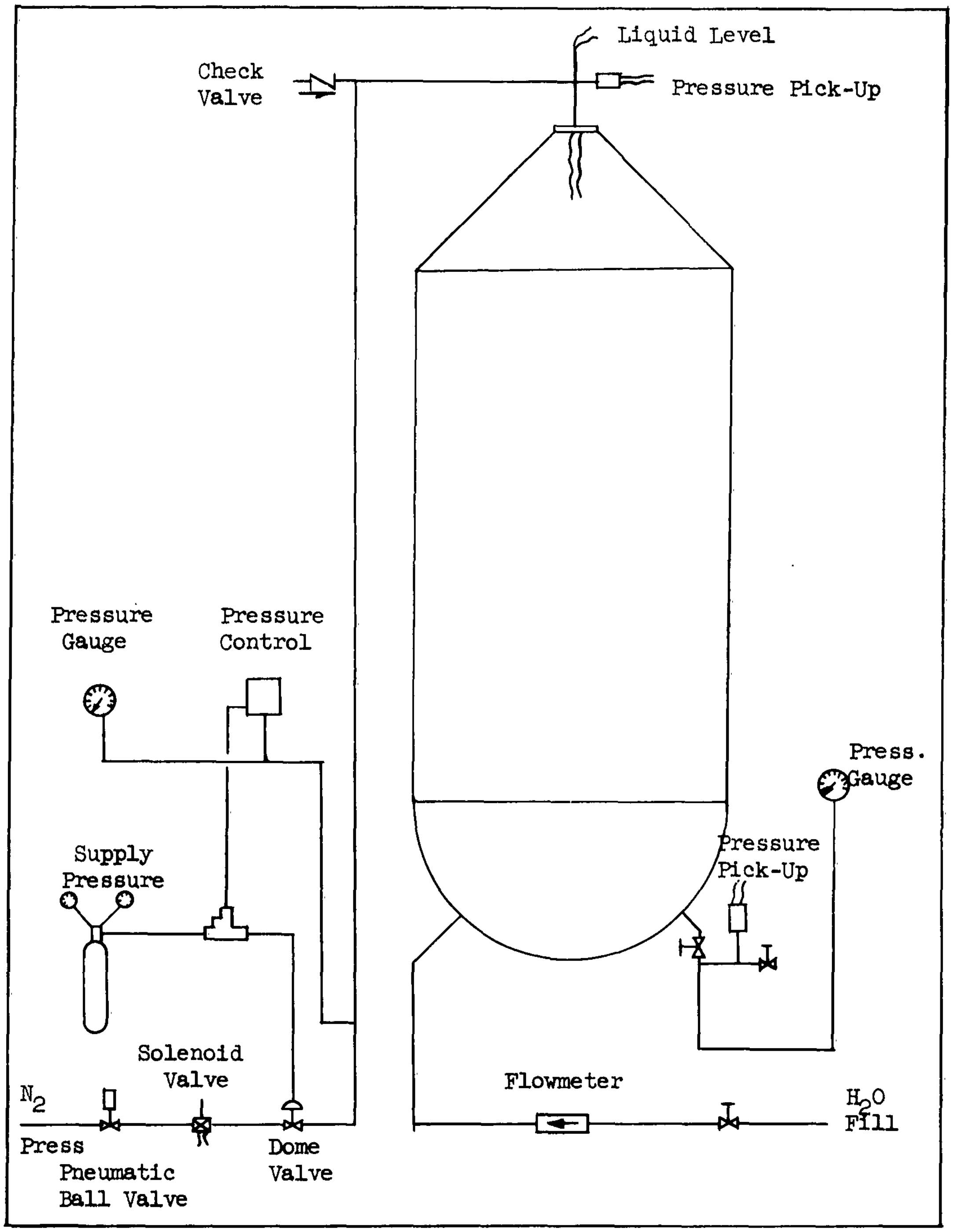


FIGURE 10
TOTAL PRESSURE LESS HYDROSTATIC PRESSURE
Vs.
STRAIN

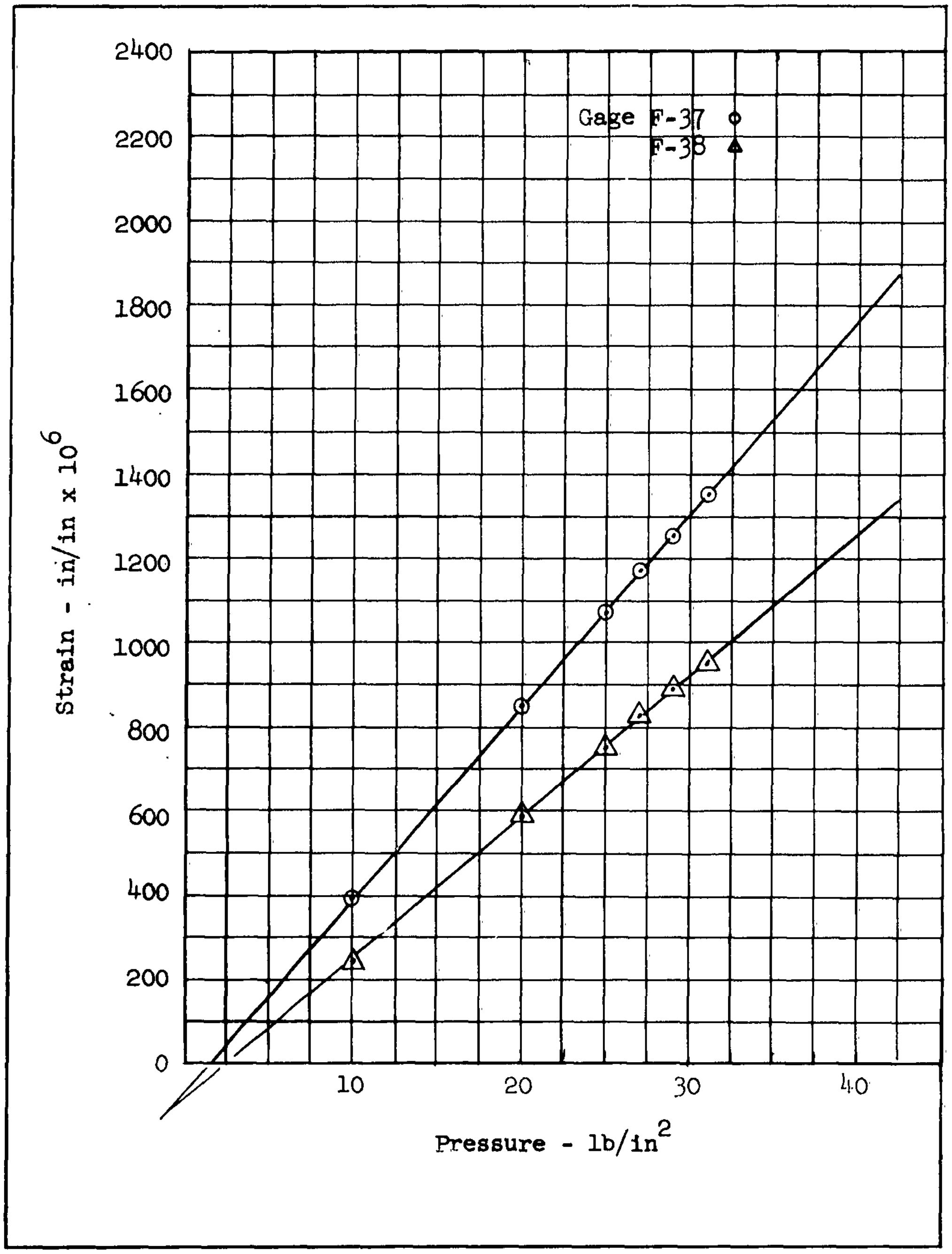


FIGURE 11
MERIDIONAL STRESS
7,000 GALLON TITANIUM TEST TANK

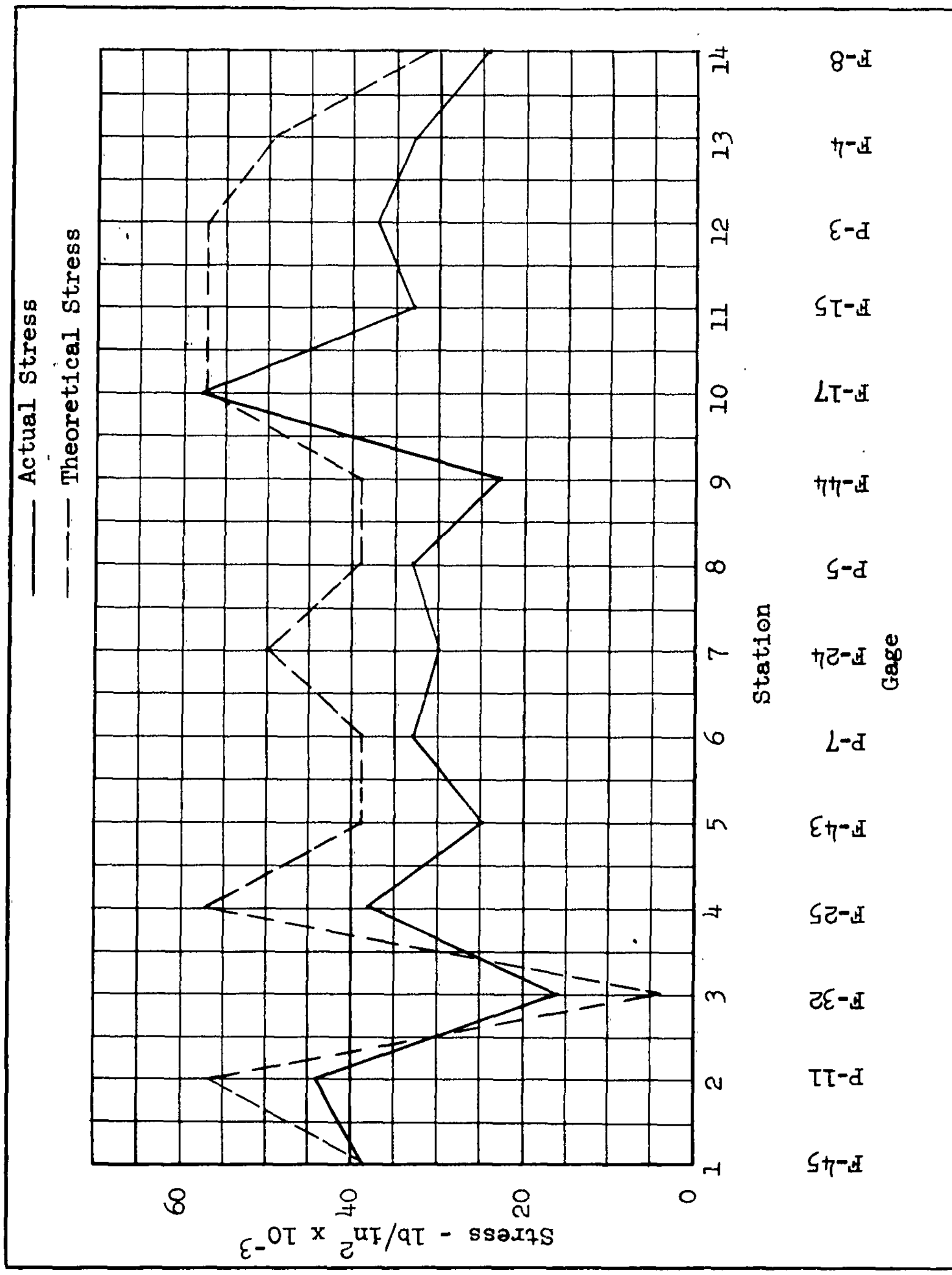
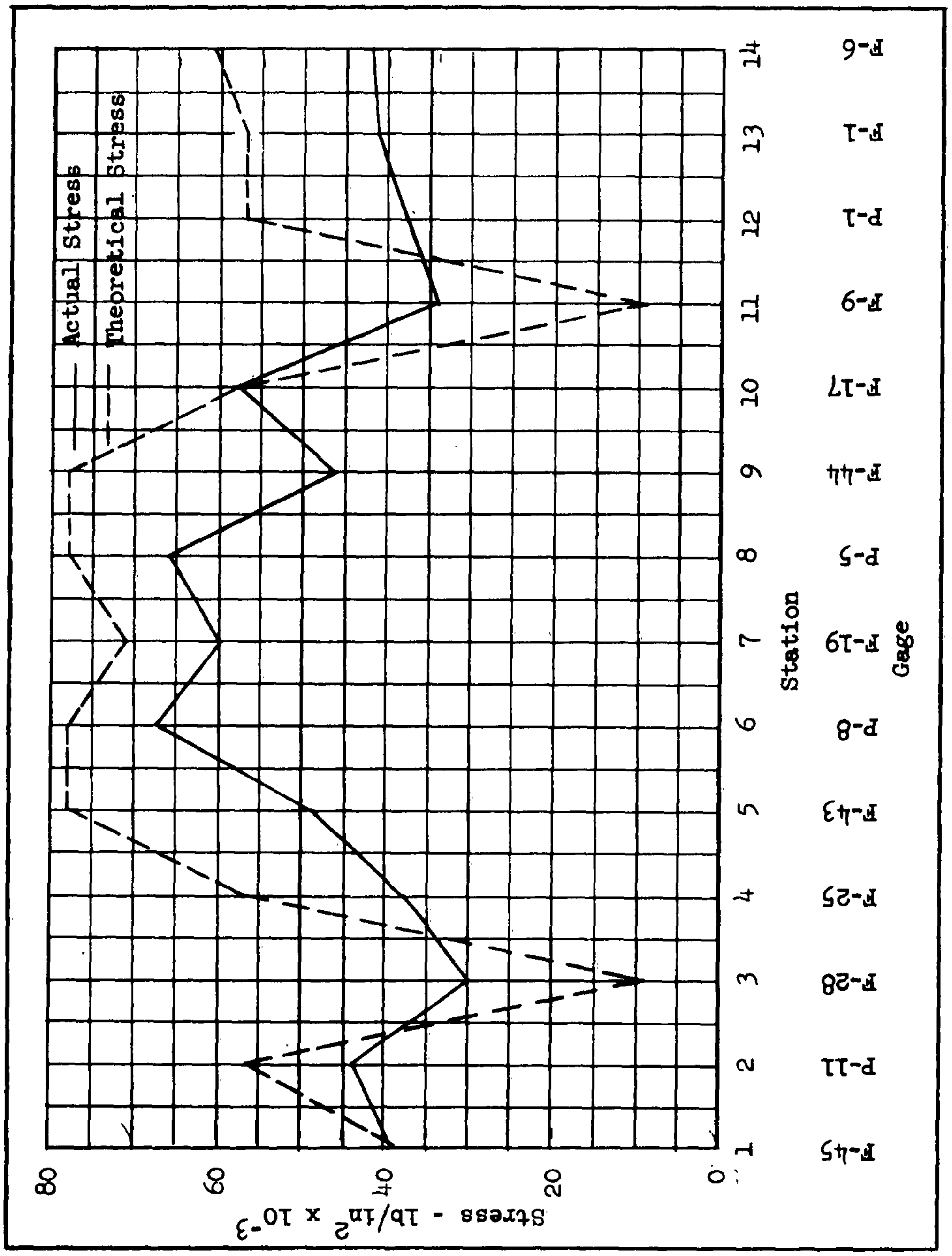


FIGURE 12
CIRCUMFERENTIAL STRESS
7,000 GALLON TITANIUM TEST TANK



Conclusions

In general, the actual stresses were less than the theoretical stresses. Figures 11 and 12 show that the two stresses followed the same trend. The major exception to this rule occurs at the foam-filled areas where the actual stresses were higher than the theoretical.

The data indicate that the stress concentrations at discontinuities are not as serious as would be expected from a theoretical analysis.

In the theoretical analysis it was assumed that the foam filler between the skirt and the tank shell produced a fixed condition in the shell material in contact with the foam. The strain gage readings indicate that better correlation is obtained if the effects of the filler are ignored.

The results show that a reasonably accurate analysis may be made in designing large titanium tanks. No problems exist in designing fittings of sufficient strength at junctures. It is quite possible that the design of components at these discontinuities may be overly conservative.

Figure 13 shows the tank being removed from the test tower after successfully completing the hydrostatic test. Figure 14 shows a four-man lift of the tank to emphasize the lightweight construction.

1.1.3 Tank Insulation

Insulation of the titanium tank was begun the latter part of January. Formed segments of fiberglass have been trimmed and fitted to the forward and aft heads. The segments are attached to the head with Sta-Bond 511-A adhesive. Thermal stand-offs have been installed on the manhole, instrumentation port, and vent port. Retainer angles which attach the insulation segments to the skirt and poured foam area have been installed. Figure 15 shows a cross-section of the head area indicating the work done to date.

1.2 7,000 Gallon Stainless Steel Test Tank System

This section will be described in two parts: tank fabrication progress and thermal testing.

1.2.1 Tank Fabrication Progress

As reported in the previous quarterly report dated January, 1962, the stainless steel tank has been reworked and reinsulated and installed in the thermal test facility. No further changes have been made in the tank structure or the insulation concept.

FIGURE 13
PHOTOGRAPH SHOWING TITANIUM TANK
AFTER SUCCESSFUL HYDROSTATIC TEST

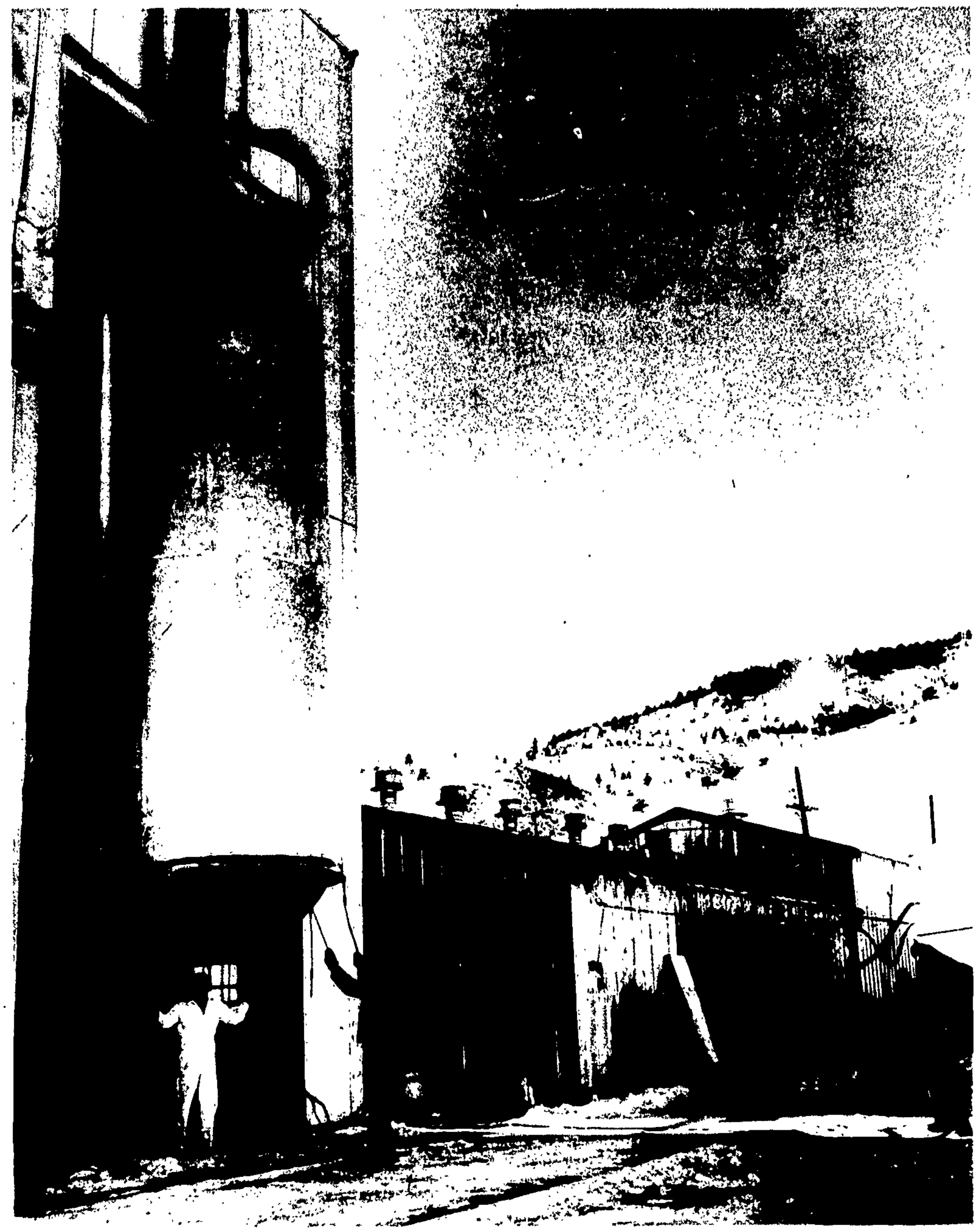


FIGURE 14
PHOTOGRAPH SHOWING FOUR-MAN LIFT
OF 7,000 GALLON TITANIUM TANK

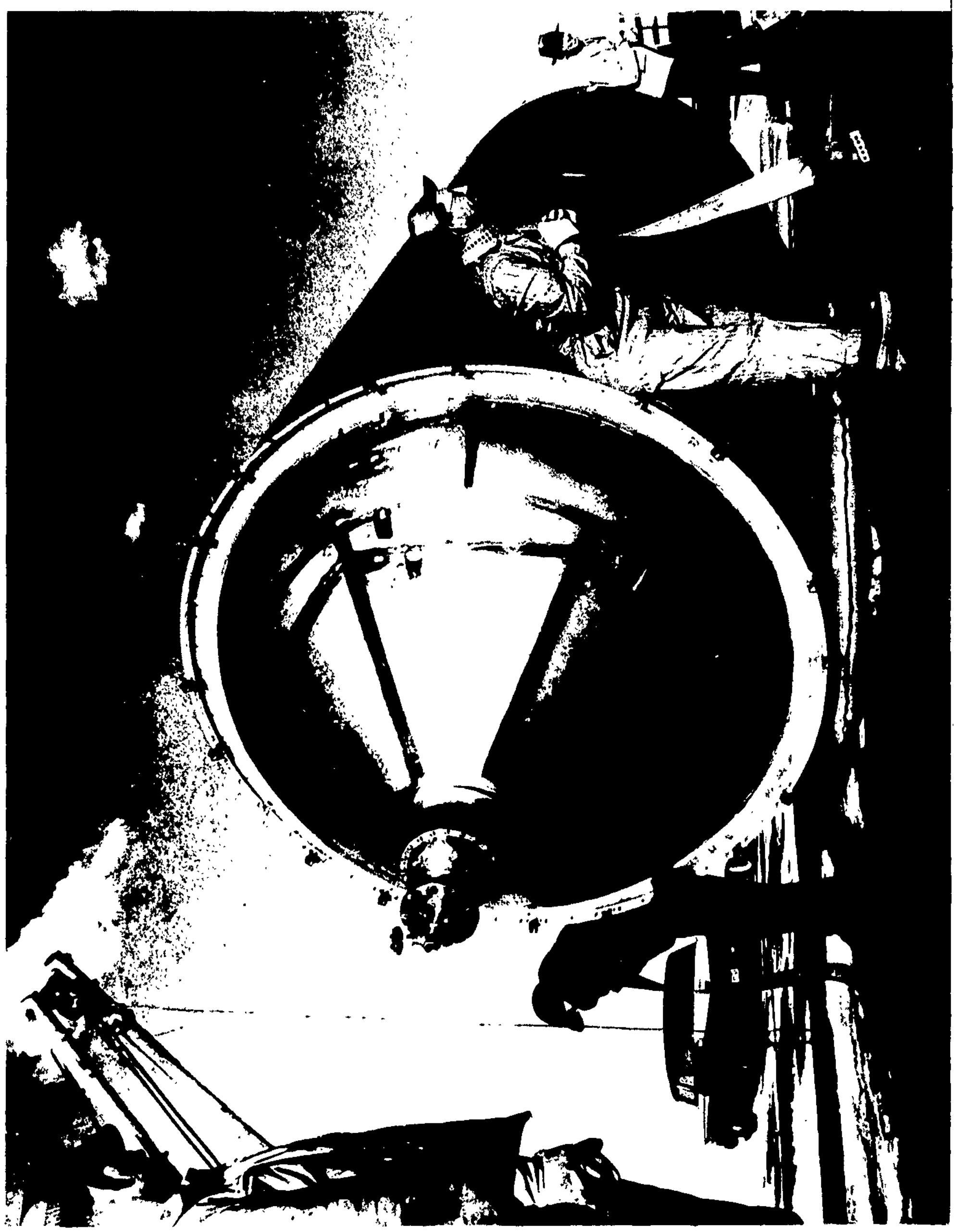
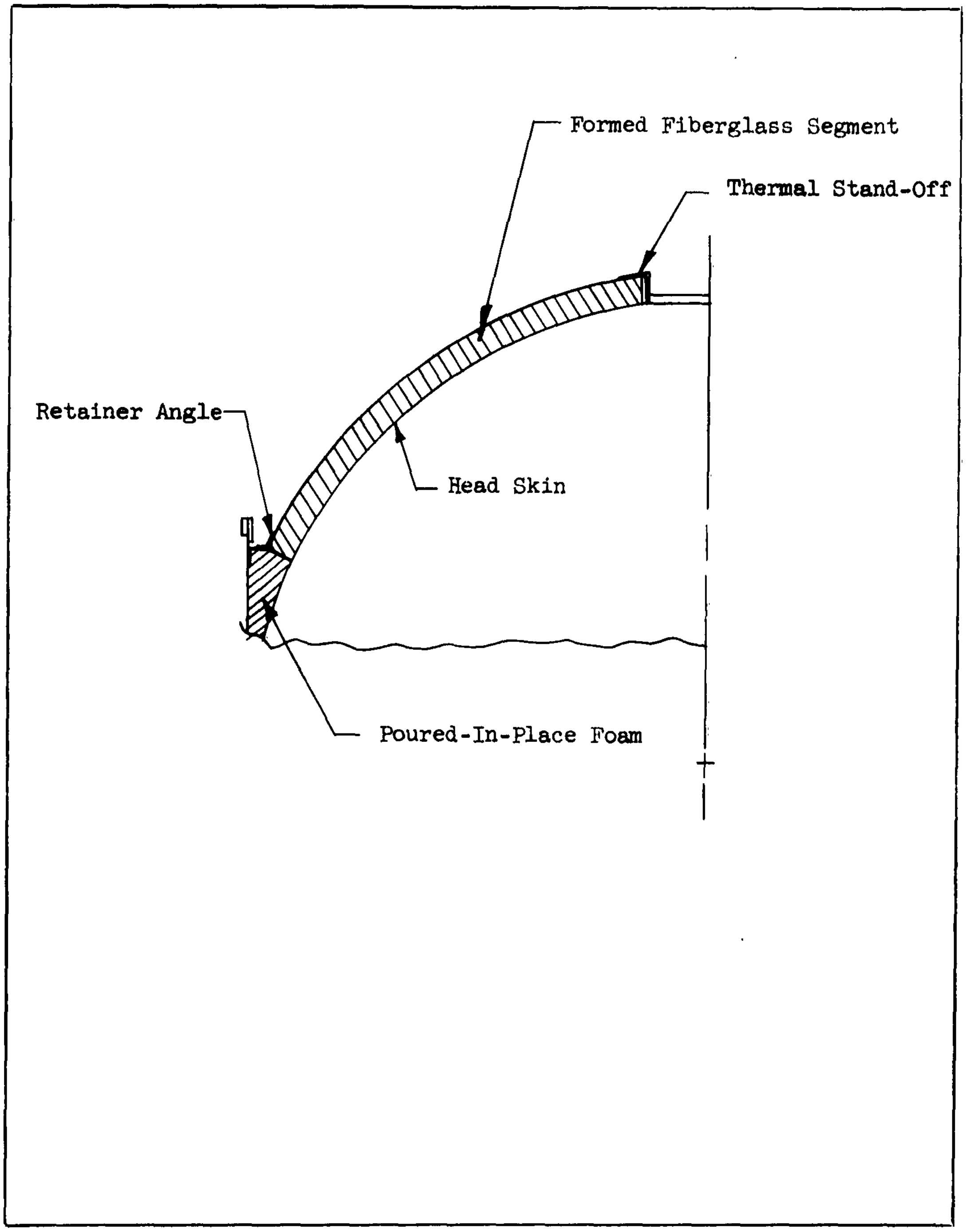


FIGURE 15
CROSS SECTION OF HEAD AREA
SHOWING FIBERGLASS INSULATION SEGMENT IN PLACE



1.2.2 Thermal Testing

This section will be described under the following sub-titles:

(a) Preliminary system check-out
(b) Testing
(c) Discussion of test data

1.2.2.1 Preliminary System Check-Out

During November, 1961, a series of fill and drain operations was performed in checking out the test tank, plumbing, data acquisition system, etc. During one of these check-out runs, the heat lamps were turned on. When the heat lamp switch was operated, all the circuit breakers on the facility were opened. A search was begun to find what had short-circuited the system.

Examination of the substation, connecting wiring, and fuse panels revealed nothing wrong. The vacuum bell cover was removed so the tank and lamps could be examined. The trouble was found to be the aluminum foil cover on the tank itself. The cover had split open from top to bottom on two sides, allowing the foil to lay over against the lamp terminals, thereby causing the short circuit. The splitting action was apparently due to an abnormal amount of contraction of the silicone rubber used to bond the aluminum foil wraps composing the cover.

The damaged cover was removed and the tank was rewrapped with a single layer of aluminum foil. The seams were sealed with an aluminum foil pressure sensitive tape. To prevent the aluminum foil from contacting the heat lamps should the cover split again, the tank was wrapped with aluminum screen wire. Figure 16 shows the tank with the new cover and screen installed.

Check-out runs were resumed after the tank covering was completed. On December 5 damage was experienced by the test tank itself. During a fill cycle, the transition cone at the bottom of the tank buckled and split open, allowing several hundred gallons of LH_2 to run out into the first work level area. No fire resulted from this rupture. Examination of the damage revealed the cone had failed completely, buckling around the entire perimeter. Figures 17 and 18 are photographs of the damaged area. It would appear that the fill and drain line had moved upward and buckled the cone.

The funnel was removed from the tank and the flanges salvaged. A new cone was welded to the old flanges and the new assembly installed on the tank. Leak checks revealed no leaks and testing was resumed.

When the damaged cone was removed, the interior was covered with a fine, white powder. Further examination revealed this fine powder up inside the tank and in the plumbing. It was determined the powder was insulation material of the type used in the insulation of the fill and drain valves for test tank and each storage dewar. These valves are enclosed in an aluminum can which is filled with the powder insulation. Each can

FIGURE 16
PHOTOGRAPH OF NEW ALUMINUM FOIL COVER
WITH WIRE SCREEN PROTECTOR ON STAINLESS STEEL TANK

FIGURE 17
PHOTOGRAPH OF DAMAGED TRANSITION CONE (1)

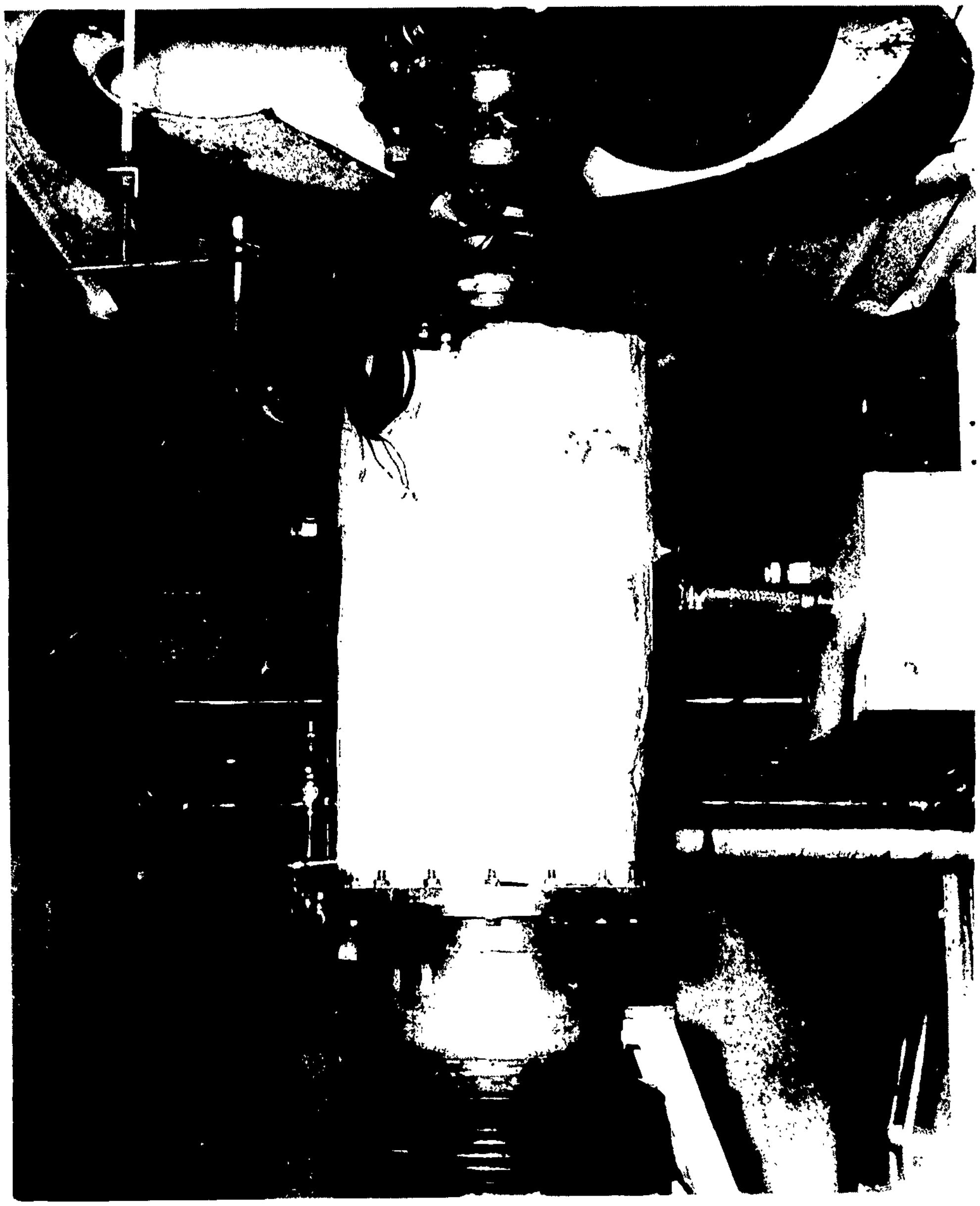


FIGURE 18
PHOTOGRAPH OF DAMAGED TRANSITION CONE (2)

was opened and a bad leak was found in the fill valve to the test tank. A teflon gasket had failed which allowed the powder insulation to be drawn into the fill line and distributed throughout the plumbing system. The valve was repaired and the plumbing cleaned of insulation powder.

Three possibilities exist that could have caused the failure of the transition cone.

(a) Overpressurization of the fill line
(b) Explosion in fill line
(c) Excess insulation plugging filter

Check-out of the thermal facility was resumed and was found to be operational.

1.2.2.2 Testing

During the latter part of November, a meeting was held with Edwards Air Force Base personnel, and it was agreed that the major emphasis of the thermal test program would be the study of stratification phenomena. To accomplish this, a special temperature probe was installed to study the stratification phenomena in the upper or lower region of the test tank.

Thermal testing began in December, 1961. Several preliminary runs were made (without recording data) for a final check on the entire system. On several occasions when the run button was pushed, the system would short-circuit and stop. It was first thought that the insulation may have opened up again and had made contact with the lamps again even though they were protected by the screen wire covering. A check of the tank revealed that the cover was intact and was not causing the trouble. The cause was then suspected to be corona discharges taking place within the evacuated bell chamber.

Earlier in the program the possibility of corona effect was discussed with DGRPT and at their request contact was made with the Martin Company, Denver, Colorado, for information on this subject. The information from Martin-Denver was limited and inconclusive. Therefore, a test procedure was devised to check the possibility of corona in the vacuum bell. A stainless steel test cylinder was installed and the bell sealed. The vacuum bell was evacuated to 20 mm Hg and then increased in .5 mm increments. At each pressure the lamps were turned up to full voltage and then back to off. At no time did corona occur.

During the time that Beech was conducting these tests, the supplier of the heat lamp system (Research, Inc.) also conducted a series of tests and forwarded their data for consideration. This information indicated that corona discharges could be obtained on a 480 volt system operating in a pressure range of approximately 1.7×10^{-2} mm Hg up to 1.1 mm Hg. The possibility of a discharge was reduced as the pressure increased above 1.1 mm Hg. Tests also were conducted by Research, Inc. on a 240 volt system with no discharge obtained.

At the time the system was designed, it was known this phenomenon was possible with a 480 volt system and that a 240 volt system would materially reduce this possibility if not entirely eliminate it. However, at the time a 240 volt system was not available from Government sources and a 480 volt system was. Therefore, the 480 volt substation was installed.

After considering the data submitted by Research, Inc., which apparently bears out the results of the tests conducted in the heat tower by Beech, it was decided that for each thermal test, a pressure would be established where corona discharge did not occur and the test would be conducted at that pressure. The only difference in conditions existing between the corona tests and the actual thermal run is the temperature. The corona tests were made at ambient temperature. What effect this might have is not known.

Following the procedure of finding a pressure where corona discharge did not occur, two thermal test runs were performed on December 12 with qualified success. Two more thermal test runs were performed on December 16 with greater success. Of the latter two runs, one was made without heat applied to the side wall and the other with heat applied to the sidewall. Results of the tests are given below.

1.2.2.3 Discussion of Test Data

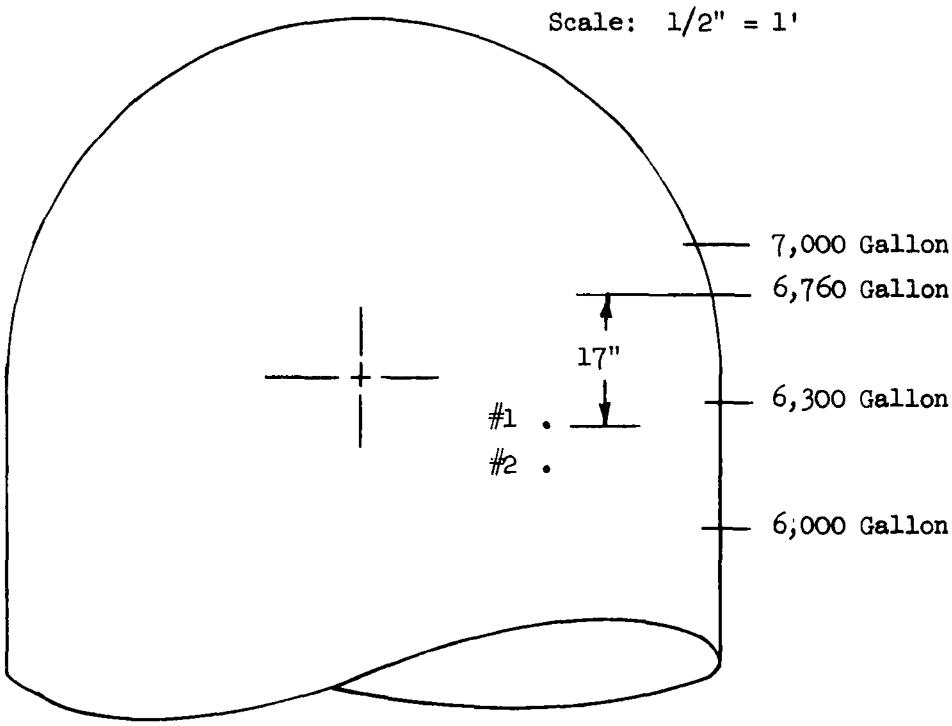
Selected data from the test runs are presented in Figures 19 through 23. This data is taken from strip charts monitoring eight channels of information during each test. Strip chart data is used since difficulties encountered in the magnetic tape recordings invalidated their contents. For a discussion of these difficulties see paragraph 1.3.2.

At zero time the tank was closed off and pressurized rapidly. The heat flow through the tank sidewall during the run is 52.45 Btu/sec and the liquid level dropped approximately 460 gallons. As can be seen, the operating pressure was reached in approximately 50 seconds and stabilized out shortly thereafter. The new operating pressure of 15 psig establishes new equilibrium conditions which are reflected in the rise of temperature of the liquid. At the same time the vent flow rate is dropping off, indicating that subcooled liquid exists during the time for equilibrium to take place. At 100 seconds the vent gas flow has stopped and the tank pressure has stabilized; meanwhile, the bulk liquid temperature is rising to its new equilibrium temperature.

At the time (approximately 200 seconds) that the liquid hydrogen reaches its new equilibrium state, the liquid boils and increases the vent flow rate as well as the tank pressure. At approximately 280 seconds the tank is vented to the atmosphere with resultant temperature drop to a new equilibrium state.

It is interesting to note the temperature stratification of the liquid during the run. The temperature probes used for plotting this data were 6 inches apart and in the same vertical plane.

FIGURE 19
LOCATION OF TWO TEMPERATURE PROBES IN TANK



Location of Two Temperature Probes in Tank

FIGURE 20
LH_2 IN TANK VS. TIME

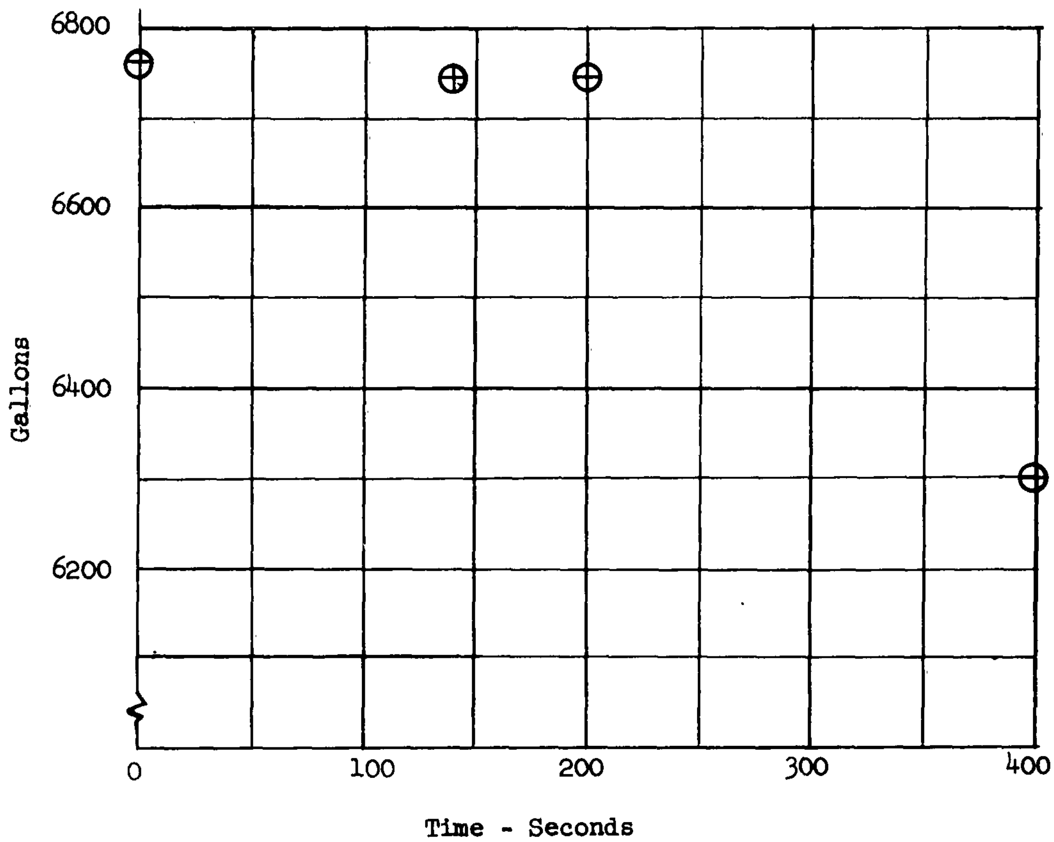


FIGURE 21
VENT FLOW RATE VS. TIME

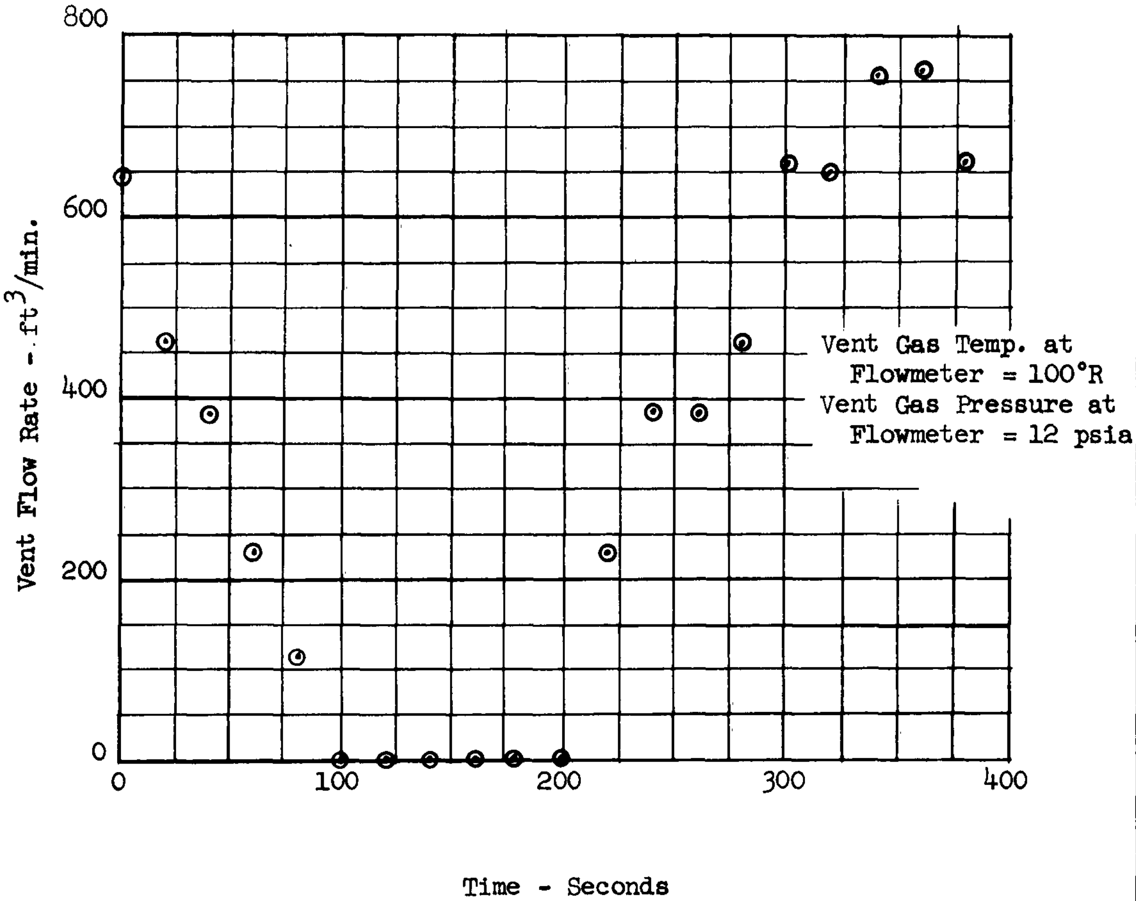


FIGURE 22
INTERNAL TEMPERATURE VS. TIME

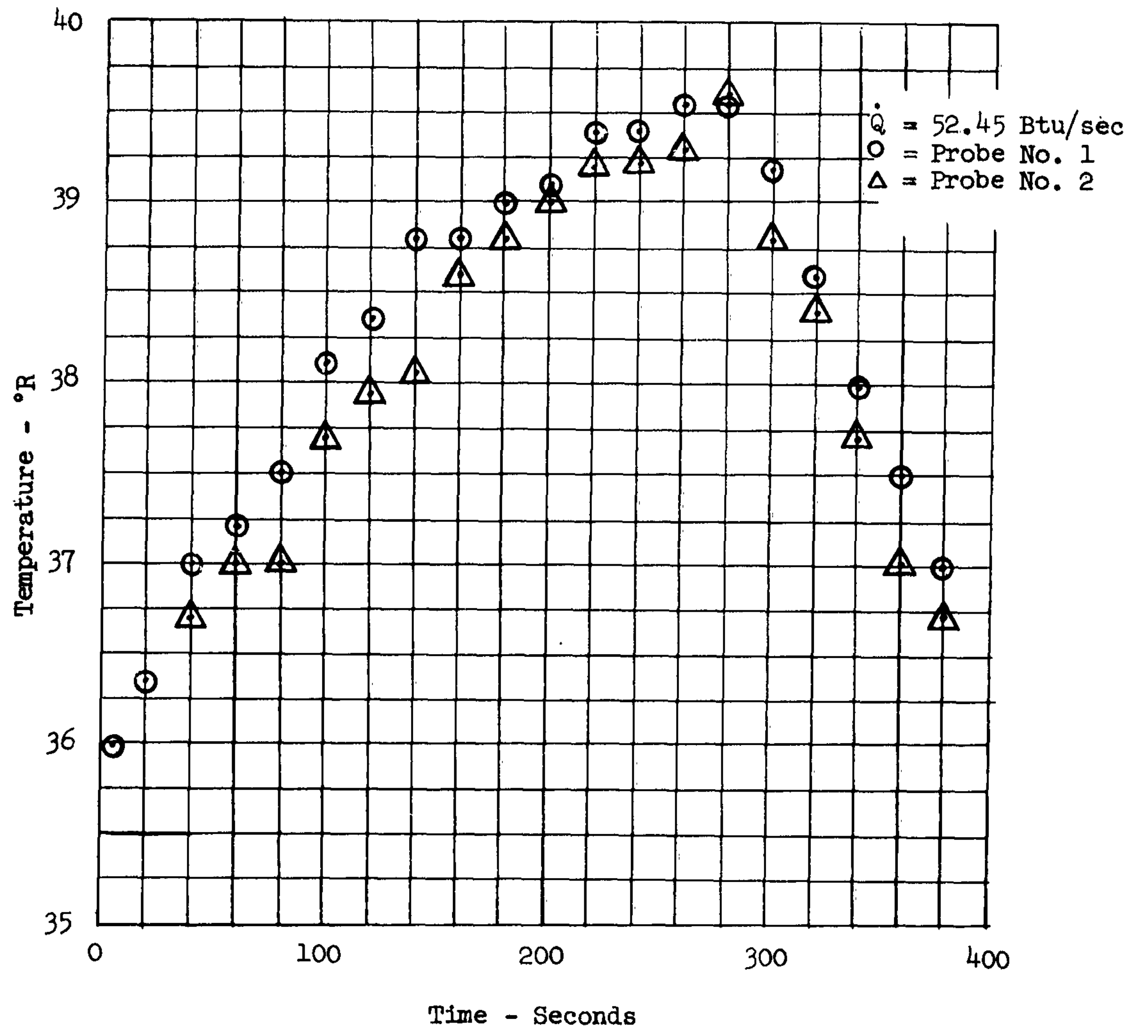
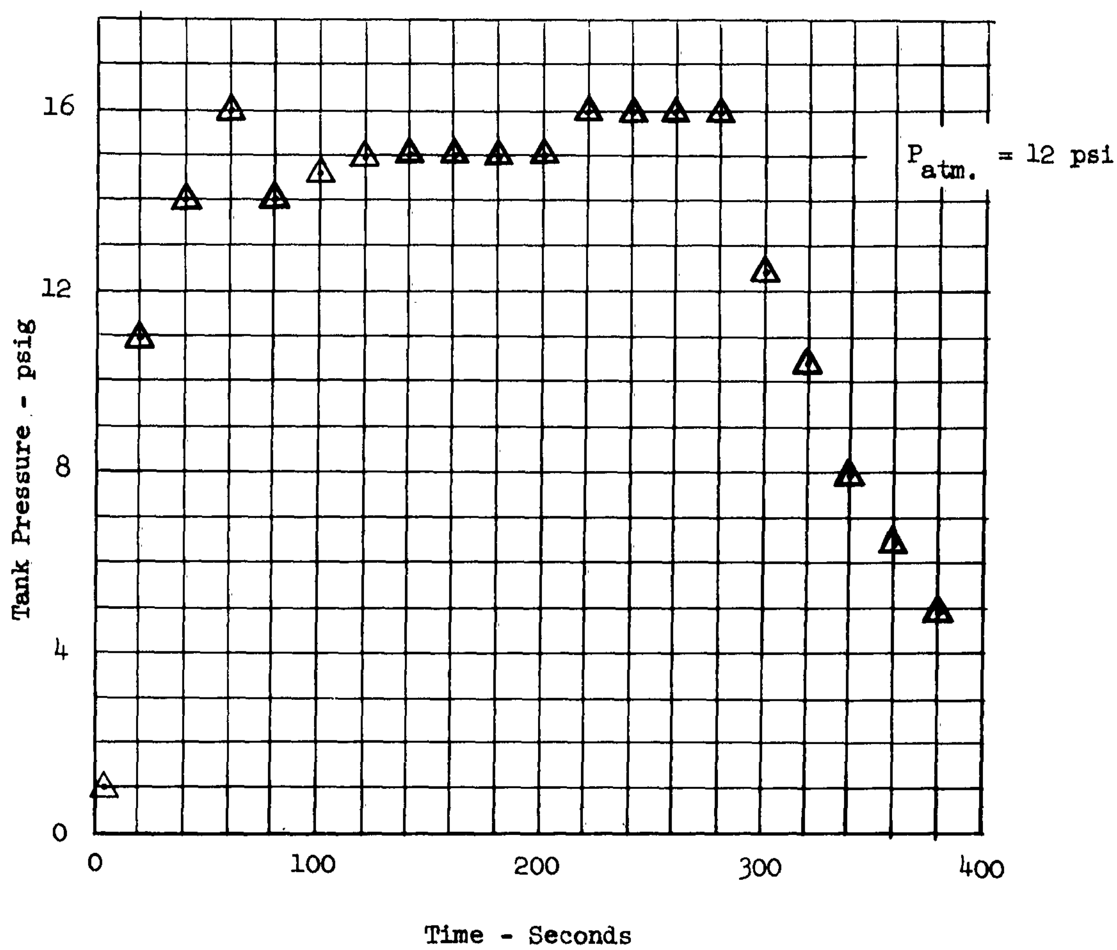


FIGURE 23
TANK PRESSURE VS. TIME



1.3 Thermal Test Facility

This section will be described under the following sub-titles:

(a) Mechanical
(b) Electrical and Data Acquisition
(c) Recommendations

1.3.1 Mechanical

With the exception of a valve gasket failure discussed previously the mechanical equipment in the facility performed satisfactorily during the thermal test runs. A problem area exists in the inflatable seal area of the vacuum bell. This problem has been discussed in previous reports.

1.3.2 Electrical and Data Acquisition

During the four thermal test runs it was believed that the data acquisition system performed satisfactorily. While each test was in progress, the system was checked by a monitor scope. No discrepancies were noted during the runs and it was assumed the data was being accurately recorded since the system is balanced out prior to each run. In addition, the eight channels of the system which are recorded on strip charts as well as magnetic tape indicated the system was performing satisfactorily. A total of 96 channels were used; with the data being taken on magnetic tape.

After the tests were concluded, the magnetic tapes were processed and data from them examined as to quality. It was found the data was widely scattered and eratic.

It is believed the difficulty was caused by the corona discharges experienced just prior to the actual run in finding the pressure the system would tolerate. This caused a loss of synchronization in the multiplex system involving the commutator and the analog to digital converter that provides the data for the magnetic tapes. Contributing to this problem is dynamic resistance in the commutator itself. These combined difficulties apparently caused a shift of data on the tape. Investigation revealed that reduction with any real meaning was impractical.

1.3.3 Recommendations

Testing of the stainless steel tank has revealed serious problems in the control of the vacuum bell pressure and in the performance of the data acquisition system. It is felt, at this time, consideration should be given to certain desired changes before testing of the titanium test tank is scheduled. The changes are recommended as follows:

(a) Fabricate and install end closures on the vacuum bell to provide a closed vacuum system not dependent on large inflatable seals.

(b) Rework the data acquisition system to eliminate those problem areas known to exist and modification to provide a more reliable system.

(c) Convert the 480 volt power supply to 240 volt to eliminate corona discharge.

It is believed that if these changes are made, the system will then be capable of taking accurate and reliable data that will be usable to a large segment of the industry.

In order to implement the recommendations as noted above, a facilities modification program was developed. The program involves approximately $52,700 and is aimed at solving the three problems discussed previously. The Air Force technical monitor has examined and approved the proposed modification.

This modification program has been forwarded through the proper channels to ASD, Dayton, Ohio and disposition is being awaited.

The R and D effort has been stopped and a time extension to the contract requested and received.

Beech Aircraft Corporation

APPENDIX A

ENGINEERING TEST REQUEST

№ 4446

FROM H. E. Sutton

DATE November 8, 1961

TO J. R. Mabbitt

CC: J. H. Rodgers

ENGINEERING DATA:

This request supercedes and cancels Test Request 4785.

TEST SETUP:

7,000-gallon, 6Al-4V test tank with strain gages per Drawing No. 6090-4037.

TEST RUN CONDITIONS:

1. Pour foam in annulus between skirt and dome at both ends of tank.
2. With tank in top-suspended, normal upright position in pretest tower at zero gage pressure record strains.
3. Pressurize tank to 5 psig and record strains.
4. Start filling tank with water maintaining 5 psig gas pressure until lower end of cylinder is wetted after which the tank may be completely filled at zero gas gage pressure.
5. Record strains and hydrostatic gage pressure on bottom of tank.
6. Increase gas pressure at top of tank; when tank is completely filled, increase gas pressure in the following increments: 10, 10, 5, 5, 2, 2 psig, recording strains and gage pressures at each increment. Do not exceed 45 psig pressure on bottom of tank.
7. Empty tank of water maintaining constant 5 psig.
8. With tank in top-suspended, inverted position in pretest tower at zero gage pressure, record strains.
9. Pressurize tank to 5 psig and record strains.
10. Fill tank with water. Record strains and hydrostatic pressure at the bottom of the tank.
11. Increase gas pressure at top of tank; when tank is completely filled, increase gas pressure in the following increments: 10, 10, 5, 2, 2, 2 psig, recording strains and gage pressures at each increment. Do not exceed 44 psig pressure on bottom of tank.
12. Empty tank and remove strain gages per Specification 7601.
13. Final tank configuration: Prepare for insulation installation.

INSTRUMENTATION:

1. Strain gages operative per locations in Specification 7601.

APPROVED J G Connelly

APPROVED

E-221

INSTRUMENTATION (Continued)

2. Pressure gages to measure:

   a. Hydrostatic pressure at lowest point of tank
   b. Gas pressure on water in tank

DATA REQUIRED:

1. Strain gage record:

   2 records per each of 56 gages.

2. Pressure readings:

   Hydrostatic and gas gage recorded on strain gage record.
   Barometric pressure at start of each day's test.

3. Temperature:

   Ambient air.
   Tank water.

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